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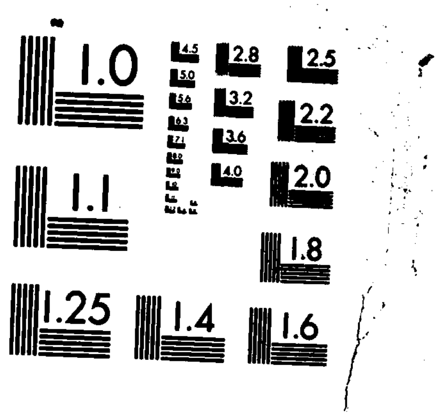

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TECHNICAL REPORT
SIMULATION EXPERIMENT

THE APPLICATION OF PERFORMANCE FEEDBACK IN SIMULATOR TRAINING: ITS EFFECTS ON THE ACQUISITION OF SHIPHANDLING SKILLS IN UNFAMILIAR WATERWAYS

DEPARTMENT OF TRANSPORTATION ★ UNITED STATES OF AMERICA ★

U.S. DEPARTMENT OF TRANSPORTATION

MARITIME ADMINISTRATION
OFFICE OF SHIPBUILDING, OPERATIONS, AND RESEARCH

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16. Abstracts

The purpose of this experiment was to determine whether providing performance feedback can improve the effectiveness of simulation in imparting shiphandling skills. Further, the relative effectiveness of two different levels of performance feedback was examined.

Two groups of six subjects made eight simulator runs through the Valdez Narrows Channel. The 2nd, 3rd, 6th, and 7th were training runs and the others were used as test runs. During the training runs one group called the augmented feedback group, was given a simulation display which highlighted the perceptual cues available to the subject. The other group, called the supplemental feedback group, had the same situation display and in addition was coached by an instructor after each training run. During the test run, no feedback was provided. As a control, the data from six subjects who had performed the same task in a previous study were used. These subjects had received no enhanced feedback and were called the intrinsic feedback group.

Learning was evaluated by comparing three groups on the test runs over a battery of shiphandling measures. Differences found between the groups prior to training were covaried out. A clear superiority in learning was exhibited by the augmented and supplemental feedback groups over the intrinsic feedback group using a one-way ANOVA procedure. The difference between the augmented and supplemental groups on individual performance measures were not significant.

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1. INTRODUCTION

The purpose of this study was to investigate the role of performance feedback in masters' acquisition of shiphandling skills through simulator training. Many maritime groups recognize the potential of simulator training for providing quick and efficient knowledge which otherwise could only be gained through years of real world experience. Realization of this potential, however, depends on the ability of the simulator training program to take into account the special cognitive needs of the individual.

The above point is clearly illustrated by the results of the CAORF study "Efficiency of Simulation in the Acquisition of Local Shiphandling Knowledge as a Function of Previous Experience" (Multer and D'Amico, 1981). This study sought to determine the amount of simulator training needed by masters with different types and amounts of experience to reach proficiency in navigating a specific restricted waterway, the Valdez Narrows in Alaska. Asymptotic performance level was the chosen criterion for this experiment because it denotes an individual's optimization of his high performance potential, i.e., when the individual has reached the point where no further consequential improvement in performance is achieved. The study found, however, that all four of the groups examined failed to achieve asymptotic levels of performance; performance potential was not optimized. The study's authors offered a possible explanation for all groups' failures to achieve asymptotic levels of performance; namely, a critical ingredient, performance feedback, may have been missing from the training process.

While the present study is not concerned with uncovering factors leading to asymptotic levels of performance, it does seek to examine the effect of performance feedback on mariners' acquisition of shiphandling skills in unfamiliar waters. The ultimate aim of this experiment is to aid in devising a training methodology resulting in optimal improvement in performance. To achieve this aim, an understanding of some of the critical factors contributing to performance feedback's effectiveness is necessary.

1.1 FACTORS CONTRIBUTING TO FEEDBACK EFFECTIVENESS

Timing is one central factor contributing to performance feedback's effectiveness. Operant learning theory states that a particular action will most likely be repeated when it is quickly followed by a reinforcement. For instance, in a training situation operant learning theory predicts that training effectiveness is increased by decreasing the time between a trainee's action and his knowledge of the action's consequences. One can easily apply this theory to harbor navigation. In harbor navigation the action may be an engine or a rudder command; the reinforcement is the master's knowledge of that action's consequences. According to operant theory, a master who saw the positive or negative consequences of his action immediately after his command was given would acquire shiphandling skills more rapidly than a master who did not quickly receive feedback about the appropriateness of his action.

Contrary to operant theory is the hypothesis that by increasing the time interval between a master's action and feedback about his action, the master has more time to think about the complex network of causes and effects which actually occur during ship maneuvering.

Redundancy is another factor influencing performance feedback's effectiveness. Harackewicz (1979) found that an increase in the amount of performance feedback produces a corresponding performance improvement only if the additional feedback provides nonredundant information. Additional feedback providing redundant information results in no performance improvement and a reduction in intrinsic motivation.

One final possible contributing factor to performance feedback's effectiveness is **personal interaction** during feedback presentation. A number of studies have found that personal presentation of feedback enhances its effect. However, this outcome is dependent on the amount of esteem and respect the trainee has for the instructor.

Guided by the aforementioned factors, it was this study's intention to present three theoretically different levels of feedback. These three feedback types were intrinsic, augmented, and supplemental feedback.

1.2 TYPES OF FEEDBACK

Intrinsic feedback theoretically provides the minimal amount of feedback. For feedback about the appropriateness of his actions to be effective, the trainee must rely solely on his perceptions of ownship's movement. Intrinsic feedback, by its definition, always emanates from the situation in which the individual acts. One example of intrinsic feedback (exaggerated for the purpose of illustration) would involve a master whose ship is hugging the right side of the channel and who puts the rudder hard right, resulting in a grounding. The grounding acts as intrinsic feedback informing the master that a hard right rudder command is an inappropriate action

when hugging the right side of the channel. In such a case the feedback is almost immediate; that is, the consequence immediately follows the action.

Unfortunately, the consequences of most shiphandling actions are not so readily perceptible. For example, the turn from leg A onto leg B of the Valdez Narrows scenario is complicated by a following current (see Figure 1). If a master waits until he is close to the turn and calls for hard left rudder, the port side will be exposed to the current, pushing the vessel to starboard. However, at the same time as the ship is drifting right, the bow is swinging to the left, making the consequence of his action much less perceptible.

It can be seen that intrinsic feedback is always available, and will probably be used by all the groups in all runs in this study. Therefore, the intrinsic group serves mainly as a control against which the additional benefits of the other types of feedback can be assessed.

Augmented feedback theoretically provides moderate levels of feedback. Augmenting the intrinsic feedback allows the master to easily perceive the consequence of his action. In this study augmented feedback entailed providing the trainee with a situation display on the bridge. This display presented a dynamic, graphic representation of ownship, trackline, and the surrounding land masses and navigational aids. Moreover, it illustrated ownship's true motion through the use of a six minute true motion vector.

Because intrinsic feedback refers to a trainee's own attention to the consequences of his actions, it is almost impossible to introduce any other type of feedback into a training situation without it also blending with the trainee's own intrinsic feedback system. Thus a training situation which utilizes augmented feedback will also contain some intrinsic feedback.

Although intrinsic and augmented feedback may help a student determine the appropriateness of a particular action in

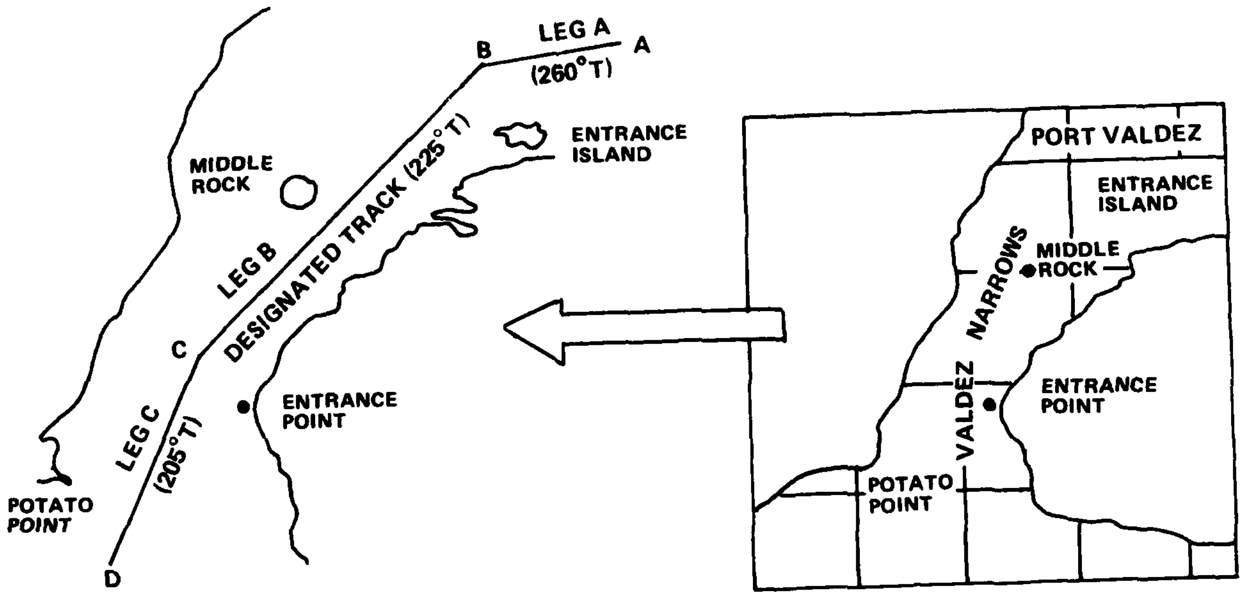

Figure 1. Valdez Study Area

a particular situation, these types of feedback do not necessarily help him to determine interrelationships between multiple situations, actions and consequences. **Supplemental feedback**, however, does address this issue. When handling a ship, the master's attention and energies are split between many different concerns, leaving limited mental resources available to integrate much information across changing situations. However, by removing the master from the task at hand he may gain a new perspective on his actions, gain an understanding of interrelationships of cause and effect across various situations, and learn to apply this understanding to shiphandling under many conditions. A static display of information in the form of a trackplot presented to the master after he has been removed from the shiphandling situation may aid him in integrating information from several different sources. Also, an instructor may help develop the ability to see interrelationships of cause and effect by providing the individual with insights concerning a particular action and its outcome. Supplemental feedback incorporates all these aspects which may aid the trainee in integrating information as well as aspects which help him to determine the appropriateness of a particular action.

1.3 SUMMARY

Stated simply, intrinsic feedback consists solely of the information the subject is able to garner directly from his perceptions of the consequences of his actions within the task situation. Like intrinsic feedback, augmented feedback also occurs within the task situation. It consists of the same information that might be garnered directly from the task situation; however, it presents this information in a way which is easily perceived by the subject. Supplemental feedback consists of augmented feedback supplemented by a personal presentation of information outside the task situation in such a way as to promote an integrative processing of cause and effect across specific situations through the run. Each of the feedback conditions was examined in this study for its effect on the acquisition of shiphandling skills.

2. OBJECTIVES

The objectives of this research were to test the following hypotheses:

1. The group receiving enhanced feedback (augmented or supplemental) would perform significantly better than the intrinsic feedback group.

2. Supplemental feedback would be significantly more effective than augmented feedback in promoting and understanding of the long range consequences of shiphandling action. Thus, the supplemental feedback group would perform significantly better than the augmented feedback group, once both groups had mastered the basic skills concerning the immediate consequences of shiphandling action.

3. EXPERIMENTAL METHODOLOGY

3.1 OVERVIEW

Three groups of six masters each were selected for this study. The intrinsic feedback group consisted of six masters who had no real or simulated Valdez experience prior to their participation in a 1981 CAORF study. As part of the 1981 study, this group was required to make eight simulator runs over two days on a 65,000 DWT tanker outbound through Valdez Narrows (see Figure 1). Each of the augmented and supplemental feedback groups consisted of six masters with a year of experience on a 30,000 (or greater) DWT vessel but no real or simulated Valdez experience. These masters were randomly assigned to either the augmented or supplemental feedback conditions and were given a total of eight runs outbound through Valdez Narrows over two days. On both days each master in the augmented and supplemental groups completed four runs; the second and third runs each day were feedback runs and the first and fourth runs each day comprised that day's pretest and posttest, respectively. Augmented feedback consisted of a video situation display present on the bridge during each feedback run. This display illustrated ownship's position relative to the ideal trackline, and ownship's true motion vectors in six minute segments. Supplemental feedback consisted of augmented feedback during the feedback runs plus the presentation after the feedback run of a hard copy trackplot of ownship's position and rudder angle by an instructor. The instructor was told to provide constructive criticism to the trainee at this time while also pointing out the positive features of the subject's run. Subjects in all groups, including those in the 1981 study, were instructed to maintain a speed of six knots throughout their runs and to keep their ship as close to the ideal trackline as possible.

This experiment was a three group quasi-experimental design in which the three groups were levels of the independent variable, type of feedback.

3.2 SUBJECTS

A total of twenty subjects were included in the original data pool for this experiment. Six subjects were run in 1981 as

part of another study called "Efficiency of Simulation in the Acquisition of Local Shiphandling Knowledge as a Function of Previous Experience" (Multer and D'Amico, 1981). Five of these subjects were deemed suitable to include in the present study. A total of fourteen subjects were run from February to April 1982. The first twelve subjects were randomly assigned to either the augmented feedback or the supplemental feedback conditions. One subject in the supplemental feedback condition was eliminated when it was discovered during debriefing that he completely discounted the feedback information and believed the ideal trackline to be 300 feet port of the position specified by charts and other information provided to him. The thirteenth subject replaced this subject (#8) in the supplemental feedback condition. The fourteenth subject was run to fill the intrinsic group's complement to six subjecs.

3.3 EXPERIMENTAL DESIGN

The study was a non-randomized three group quasi-experimental design (Kirk, 1968). The three groups — Intrinsic, augmented, and supplemental — can be considered to be separate levels of the independent variable, type of feedback. The dependent variables were the following performance measures:

- Mean off track deviation (not signed for port or starboard)
- Maximum off track deviation (not signed for port or starboard)
- Maximum port deviation
- Maximum starboard deviation
- Swept path
- Percent of time out of a 720′ wide tolerance band.

Performance was assessed through the use of multiple pretests and posttests: one each on both the first and second days. Training runs were sandwiched between each day's pretest and posttest (see Table 1).

3.4 PROCEDURE

Each master participating in the research was told that the purpose of the project was to determine the amount of simulator training necessary for masters to become familiar with the port of Valdez. No mention was made of examining performance feedback. They were not told that any group was receiving treatment different from their own. This was done to reduce the likelihood of different group behavior because of group expectancies and to provide subjects in the augmented and supplemental group with an experience as identical as possible to that of the intrinsic group run in 1981.

Before being taken out on the CAORF bridge each subject was given a set of written instructions which were also read to him. These instructions can be seen in Appendix C. Following the presentation of instructions, each subject was completely familiarized with the CAORF bridge and simulated ownship handling characteristics. Ownship was a 65,000

TABLE 1. TRAINING TRIALS IN WHICH FEEDBACK WAS GIVEN FOR EACH EXPERIMENTAL GROUP

		Simulator Training Trial							
		Day 1				Day 2			
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8
Experimental Groups	Intrinsic Feedback	N	N	N	N	N	N	N	N
	Augmented Feedback	N	Y	Y	N	N	Y	Y	N
	Supplemental Feedback	N	Y	Y	N	N	Y	Y	N

N = Refers to No Feedback Given
Y = Refers to Feedback Given

DWT tanker, fully loaded. Bridge familiarization consisted of a tour through the bridge with a licensed mate, (CAORF staff member), who explained the operation of all bridge equipment and instrumentation. After this tour each master went through a familiarization run consisting of a slalom course of six anchored ships. The purpose of this run was to familiarize the master with the handling characteristics of a 65,000 DWT tanker and with the bridge equipment layout.

Following familiarization each master undertook a run outbound through Valdez Narrows with no feedback. The scenario was identical to the one used in the 1981 Valdez study (see Figure 1). The goal of each subject was to follow the track designated A B C D in Figure 1: the United States Coast Guard recommended track outbound through the Valdez Narrows from the port of Valdez, Alaska. Wind and current approximated that normally found in Valdez. Wind intensity varied from 30 knots from point A to Middle Rock to 40 knots south of Middle Rock. Current was constant throughout the channel in a southwesterly direction. All runs were conducted in daylight with seven miles visiblity. All performance measures were recorded automatically by computer. Runs were terminated when the ownship's center of gravity was perpendicular to line C D at point D.

After this first run each master was taken to the chief officer's day room while another master made the same run through Valdez Narrows. Two subjects alternated runs throughout both days of training. When both subjects were finished with their first runs (pretests) the training runs began. In the intrinsic group tested in 1981 these runs were the same as the first run. For the augmented and supplemental groups, however, a dynamic situation display was added. It dynamically illustrated ownship position relative to the ideal trackline on a video screen and provided 6 minute motion vectors. Following the training runs the masters in all groups were taken to the "chief officer's day room" where they could spend leisure time. Subjects in the supplemental condition at this time received a track plot showing their ship's position every 30 seconds relative to the ideal trackline. A qualified instructor who had observed that previous run also provided personal feedback by pointing out to the master where certain actions had resulted in either good or poor performance. Subjects in the other two groups read magazines or amused themselves in some other manner during the between-run time intervals.

Following two training runs, each master received his posttest for that day. This again consisted of an outbound run through Valdez Narrows.

4. RESULTS

4.1 DATA ANALYSIS

The experimental data were analyzed through an analysis of covariance subprogram in the SPSS software package. Analyses were conducted among all three experimental groups and between just the augmented and supplemental groups alone. All performance measures were compiled both over the entire run and in each of the three legs of the Valdez scenario. Analyses of covariance examined the effect of feedback over the entire training period, over the first day alone, over the second day alone, and over the interval between the first and second days. These analyses consisted of comparisons among the three groups, and the augmented and supplemental groups alone for the following trials: 1) trial 8 with trial 1 covariate; 2) trial 4 with trial 1 covariate; 3) trial 8 with trial 5 covariate; and 4) trial 5 with trial 4 covariate.

The analysis of covariance (ANCOVA) is a procedure which compensates for certain sources of bias in the experimental results. In pretesting the groups of subjects (trials 1 and 5) it was noted that there was a fair amount of variability among the groups at the outset. Comparing absolute differences in performance among groups at the end of the training would not have indicated how much of these differences were attributable to the feedback treatments, and how much to inherent differences in skill among groups. Therefore, the ANCOVA procedure was used as a means for taking these inherent differences into account and removing them from the experimental effects. Since the analysis examined the posttest performance of each group as a function of the pretest performance, it can be seen as a measure of improvement rather than of absolute level of performance. This improvement was quantified by changes in performance over time and can therefore be described as a rate of learning. By using ANCOVA, the effect of different types of feedback on rate of learning was analyzed. For a description of the ANCOVA procedure, see Kirk (1969, p. 455).

4.2 RESULTS ACROSS ALL THREE GROUPS

Results reported in this section refer to performance measures collected during the entire run through the Valdez Narrows Channel.

Means and standard deviations of each performance measure for all three groups on each test trial are presented in the tables found in Appendix A. Summary Tables for three group analyses of covariance are presented in Appendix B. Tables are ordered in the same sequence in which they are

discussed in the text and are categorized by whether they pertain to legs A, B, C or to the entire run including turns.

4.2.1 Entire Run

Trial 8 with Trial 1 Covariate. Between group comparisons for all dependent measures were significant at the 0.05 level ($p < 0.05$). Group mean scores adjusted for the covariate exhibited a consistent pattern: performance was best (i.e. group means were lowest) in the supplemental group, followed by the augmented and intrinsic groups respectively. The largest gap was between the intrinsic feedback group and the other two groups. The only exception to this pattern was on the measure Maximum Port Deviation. Here the intrinsic group demonstrated the best performance, followed by the supplemental and augmented groups, in that order.

Trial 4 with Trial 1 Covariate. All dependent measures with the exception of Maximum Port Deviation were significant at the 0.05 level. Adjusted mean scores for all significant measures were lowest for either the supplemental or augmented groups and highest for the intrinsic group.

Trial 8 with Trial 5 Covariate. The only difference significant at the 0.05 level was Maximum Port Deviation. On this measure the intrinsic group had the lowest adjusted mean score, with a difference of over 130 feet between that group's score and either of the other two groups' adjusted mean scores.

Trial 5 with Trial 4 Covariate. There were no significant effects.

4.2.2 Each Leg

Results reported in this section refer to performance measures collected for each discrete leg — A, B, C — of the USCG recommended trackline (see Figure 1).

4.2.2.1 Leg A

Trial 8 with Trial 1 Covariate. Only one dependent measure, Swept Path was significant at the 0.05 level. On this measure adjusted mean scores were lowest in the supplemental group, followed by the augmentd and intrinsic groups, in that order.

Trial 4 with Trial 1 Covariate. Maximum Port Deviation, Maximum Starboard Deviation and Swept Path were significant at the 0.05 level. The intrinsic feedback group had the lowest adjusted mean score for Maximum Port Deviation, followed by the augmented and supplemental groups. The intrinsic group, however, exhibited the highest mean scores for Maximum Starboard Deviation and Swept Path, followed in order by the augmented and supplemented groups on Maximum Starboard Deviation and the supplemental and augmented groups on Swept Path.

Trial 8 with Trial 5 Covariate. There were no significant differences for any of the performance measures.

Trial 5 with Trial 4 Covariate. Only one measure, Maximum Off Track Deviation, exhibited significant differences at the 0.05 level. Again the intrinsic group displayed the highest adjusted mean scores, followed respectively by the supplemental and augmented groups.

4.2.2.2 Leg B

Trial 8 with Trial 1 Covariate. Only Maximum Port Deviation yielded significant differences at the 0.05 level. Adjusted mean scores were lowest in the intrinsic group, followed respectively by the scores of the supplemental and augmented groups.

Trial 4 with Trial 1 Covariate. Mean Off Track Deviation, Maximum Off Track Deviation and Maximum Starboard Deviation all yielded significant differences at the 0.05 level.

On all these measures the intrinsic group had the highest adjusted mean scores, followed by either the augmented or supplemental group.

Trial 8 with Trial 5 Covariate. Only on Maximum Port Deviation were any differences significant at the 0.05 level. The intrinsic group displayed the lowest adjusted mean score on this measure, followed by the supplemental and augmented groups, in that order.

Trial 5 with Trial 4 Covariate. There were no significant differences for any of the performance measures.

4.2.2.3 Leg C

Trial 8 with Trial 1 Covariate. There were significant differences for all performance measures except Maximum Port Deviation. On all significant measures except Maximum Starboard Deviation the order of group mean scores from lowest to highest was supplemental, augmented, and intrinsic feedback conditions. On Maximum Starboard Deviation the order was augmented, supplemental and intrinsic feedback conditions.

Trial 4 with Trial 1 Covariate. Only Mean Off-Track Deviation yielded significant differences; the augmented group had the lowest adjusted mean scores, followed by the supplemental and intrinsic groups, in that order.

Trial 8 with Trial 5 Covariate. Maximum Deviation, Swept Path, and Percent of Time Out of Tolerance Band all yielded significant differences. In all cases the supplemental group had the lowest adjusted mean scores, followed by the augmented group, while the intrinsic group had the highest adjusted mean scores.

Trial 5 with Trial 4 Covariate. There were no significant differences.

4.3 RESULTS BETWEEN AUGMENTED AND SUPPLEMENTAL GROUPS ALONE

Over all comparisons and all dependent measures there was only one significant difference at the 0.05 level between the augmented and supplemental groups. This significant difference appears on the second day only (Trial 8 with Trial 5 Covariate) in Leg C for the dependent measure Maximum Off-Track Deviation (augmented group mean = 274.57 ft., supplemental group mean = 195.15 ft., F (1, 9) = 8.23, p = 0.019).

Since the differences between the augmented and supplemental groups can explain only a very small amount of the significance found in the three group ANOVA's, it is evident that this significance is due primarily to differences between the intrinsic group and one or both of the other two groups. The primary hypothesis being tested was that some type of enhanced feedback would yield superior learning to intrinsic feedback alone, and this contention appears to have been supported by the results. The exact source of variance was not determined since the particular type of enhancement which is most cost effective will most likely vary depending upon the length and nature of the task to be trained.

5. DISCUSSION

There are a number of noteworthy findings from this study. First of all, it is interesting to observe which performance measures tended to be most highly associated with one another. Four measures in this study, Mean Off-Track Deviation, Maximum Off-Track Deviation, Maximum Starboard Deviation, and Percent of Time Out of Tolerance Band were highly associated and thus can be seen as consistent indicators of performance. Maximum Port Deviation, on the other hand, appeared to be inversely related to these other four measures and was therfore probably a very poor way of evaluating performance. The factors specific to this project make this apparent. Most subjects experienced a sliding of the vessel to starboard when making turns to port. Since both turns were to port, the starboard deviations were large and more frequent than port deviations. The vessel sliding to starboard was the result of a combination of factors: poor timing of the turn; the moment of a large, laden vessel in a turn; and reduced rudder effectiveness. If the turn was not commenced on time or was not properly monitored, the vessel overshot the turn resulting in starboard deviations on the next leg. The master's failure to initiate the turn on time may have been due to insufficient time in leg A to fully assess environmental factors, steering characteristics and ship position. The overshot which resulted from the belated turn then had to be corrected by left rudder. However, the rudder's effectiveness was reduced by the relatively slow speed (6 kts) and slight following current (0.5 kts). This reduction in rudder effectiveness required the subjects to use greater rudder angles in order to maintain good control; until after several runs through the scenario. Slight deviations to port could actually be indicative of an attempt to compensate for overshoot. High winds gusting out of the NNE further exacerbate the problem of ship control by acting on the high windage of the vessel's superstructure (located at the aft end of the vessel), producing a pivoting motion. All these factors contributed to the vessel's starboard deviations. The small port deviations shown by some subjects may actually have been indications of the subject's successful attempt to compensate for the ship's starboard momentum after executing the turn.

It may also indicate that subjects may have correctly anticipated the large advance, characteristic of these vessels when turning, and that they may have commenced the turn at an appropriate time and position on some of the runs.

One major observation of interest is that the appearance of significant differences between the three groups appears to follow a consistent and logical pattern (see Tables B1–B31). In general, for legs A and B, many more significant differences appear for the first day than for any of the other time periods. In leg C, however, the greatest number of significant differences occur for the entire training session taken as a whole, followed by the second day, with the smallest number found in the first day. The following discussion attempts to explain this contrast in terms of the nature of the tasks and the nature of the types of feedback, and has implications for future training research.

The tasks for legs A and B are relatively independent of one another. That is to say, performance on leg A is not likely to affect performance on leg B to any great extent. Thus, carrying out these tasks is dependent on the acquisiton of discrete skills, namely trackkeeping for leg A, and negotiating a 35° turn for leg B. The presence of enhanced feedback, either augmented or supplemental, can aid the mariner in the acquisition of these skills by enabling him to see how his actions affect the tracking of the ship, and work to counter set and drift around the turn. These skills would be acquired during the first day by the two enhanced feedback groups, but would also be acquired by the intrinsic feedback group, although later on. Thus, differences are seen for performance measures analyzed at the end of the first day, but rarely for those analyzed at the end of the second day or over the overall session. The performance on leg C, on the other hand, is highly dependent on the leg B task. If the mariner is out of position after his first turn, it will be extremely difficult for him to align the ship for the second turn. Thus, it is to be expected that the skills necessary for leg C can only begin to be exhibited after mastering of the skills needed in leg B. The enhanced feedback will help with this process, but this will not become apparent until the second day, after leg B has been mastered.

This hypothesis then rests on the idea that leg C is different from legs A and B in that successful completion is dependent on the level of performance in the preceding legs. It was previously stated that the conceptual difference between augmented and supplemental feedback was that, although augmented feedback helped the subject understand the immediate consequences of his actions, supplemental feedback was necessary for learning the long range consequences of each action, and the relationships between the actions. Thus, it would be expected that the supplemental group would perform better on leg C than would the augmented group. In fact it was found that the only instance in which there was a significant difference between these groups was in leg C for the second day's runs. It is true that if supplemental feedback is superior to augmented feedback it might have been expected that more than one measure would yield significance; there are, however, several other factors which may have contributed to this outcome.

It must be emphasized that for purposes of statistical analysis, six subjects in a group is a rather small sample. A power analysis of this experiment showed that even in the case where significant differences were present, they would only have been discovered 35% of the time, due to the small number of subjects. Even though only one significant difference was shown by the formal comparisons between the augmented and supplemental groups, an examination of the data indicates that differences frequently approached significance for the second day of training.

The other factor possibly affecting the outcome of this experiment is suggested by the fact that the differences between the augmented and supplemental groups that did approach significance did so on the second day. If it is the case that supplemental feedback is advantageous primarily for the acquisition of knowledge concerning the long range consequences of actions and the relationships between them, then it would be expected that supplemental feedback would only begin to be useful after the basic skill concerning the immediate consequences of individual actions had already been mastered. Presumably this mastering takes some time to achieve and therefore it may be that this two-day study was not long enough to allow the benefits of supplemental feedback to become apparent. Figures 2 through 7 show that for five out of six performance measures, the performance of the supplemental group equaled and then exceeded that of the augmented group somewhere on the second day. (On the sixth performance measure, the supplemental group surpassed the augmented group on the first day.) While it is not certain that this trend would have continued throughout a longer training period, it seems likely that extending the project into a third or fourth day would have allowed the differences between the two groups to become significant. In any case, it is noteworthy that the adjusted mean scores for the supplemental group were better on six out of six of the performance measures taken at the end of training.

5.1 CONCLUSIONS

The results of this study strongly support the premise that providing enhanced feedback can greatly aid in the acquisition of skill during simulator training. There was a high incidence of significance in comparisons between the intrinsic feedback group and the other two groups, especially early in training. Thus, it seems fairly clear that some type of feedback is highly desirable in the acquisition of basic skills in shiphandling in unfamiliar waterways.

The notion that supplemental feedback can provide a better understanding of the long range consequences of actions and the relationships between them than augmented feedback alone, was not clearly demonstrated. However, even though there were virtually no statistically significant differences between these two groups, it must be borne in mind that the adjusted mean scores for the supplemental group were better than those for the augmented group for six out of six performance measures at the end of training. Statistical

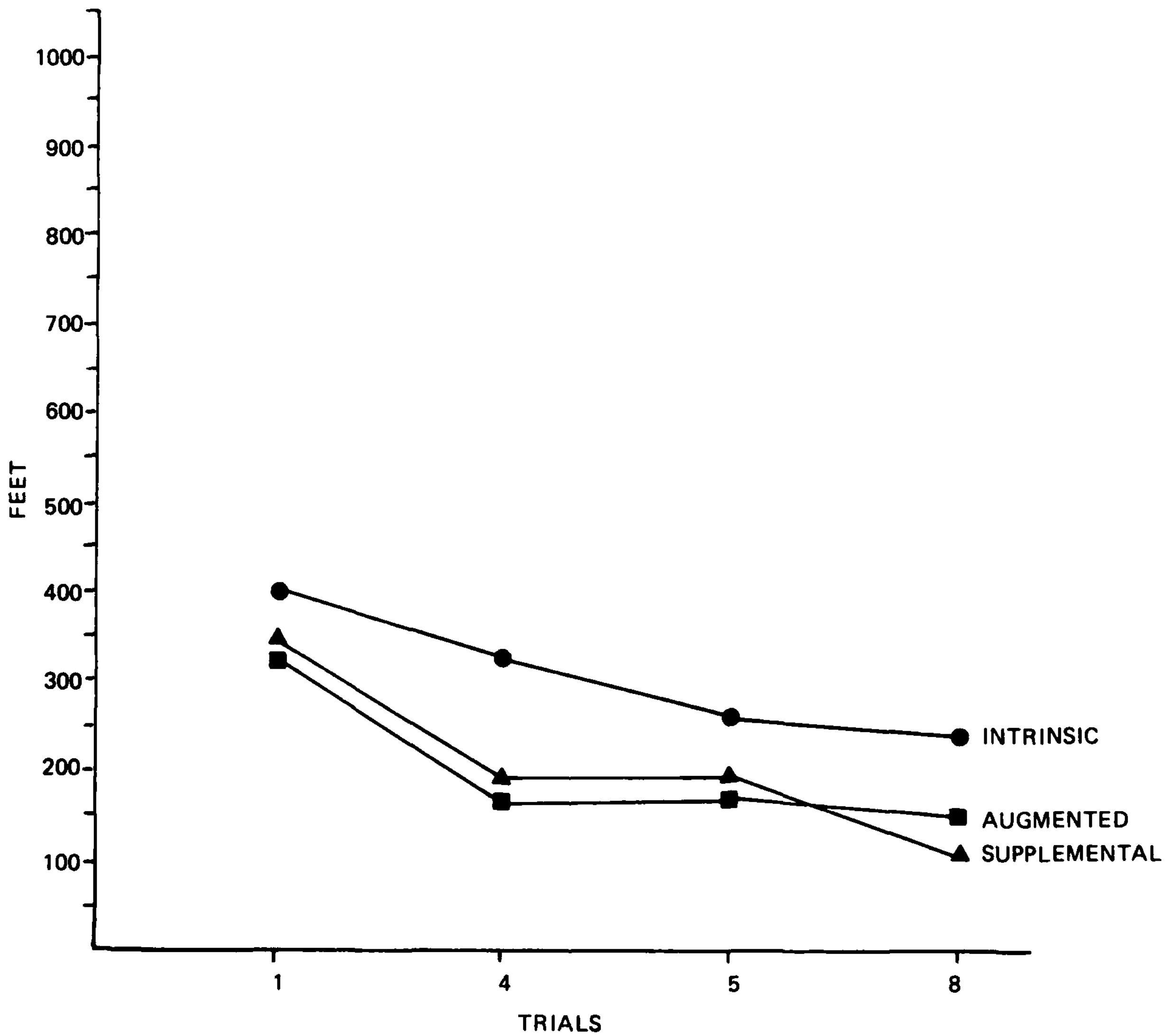

Figure 2. Mean Off Track Deviation — Entire Run

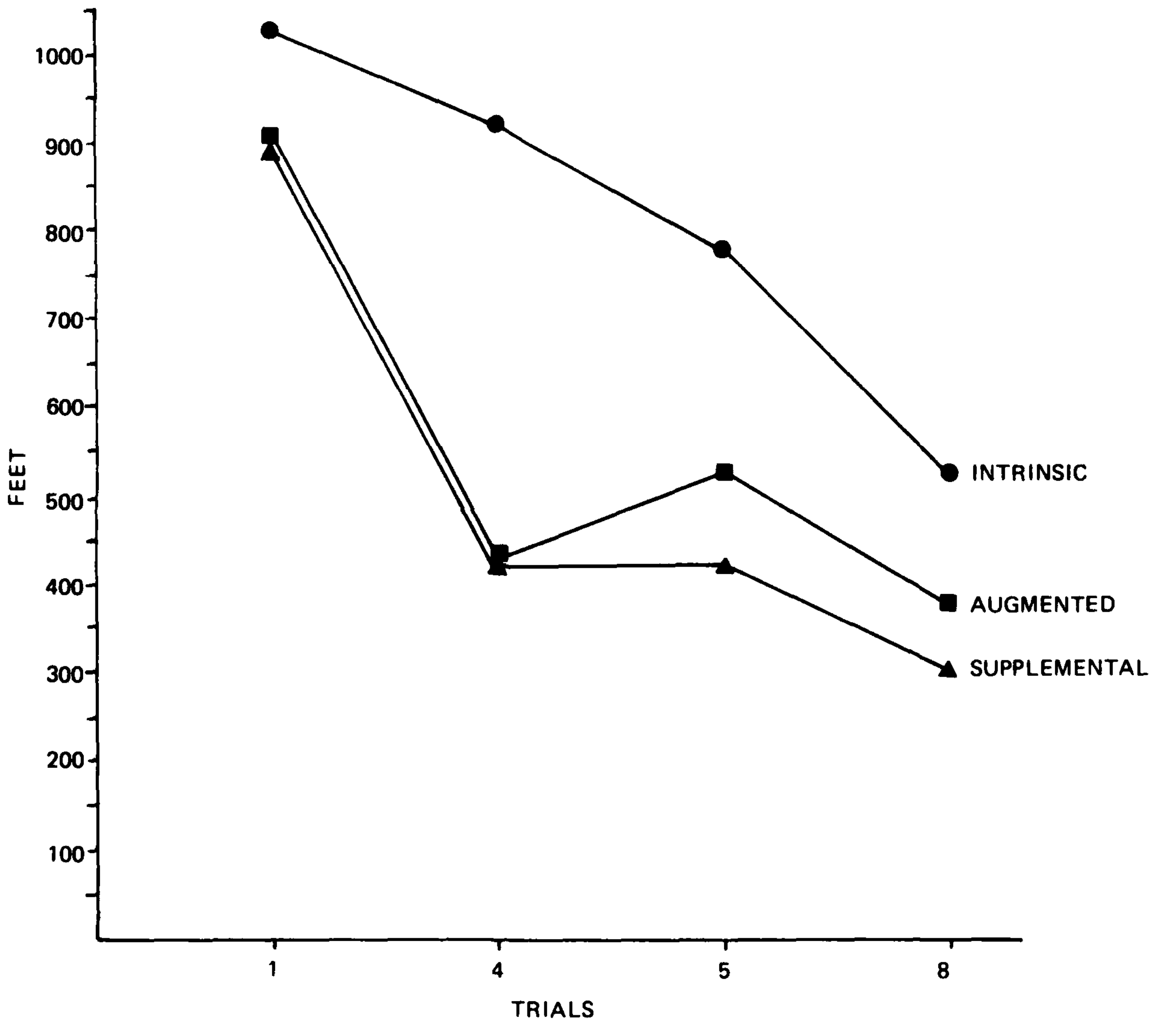

Figure 3. Maximum Off Track Deviation — Entire Run

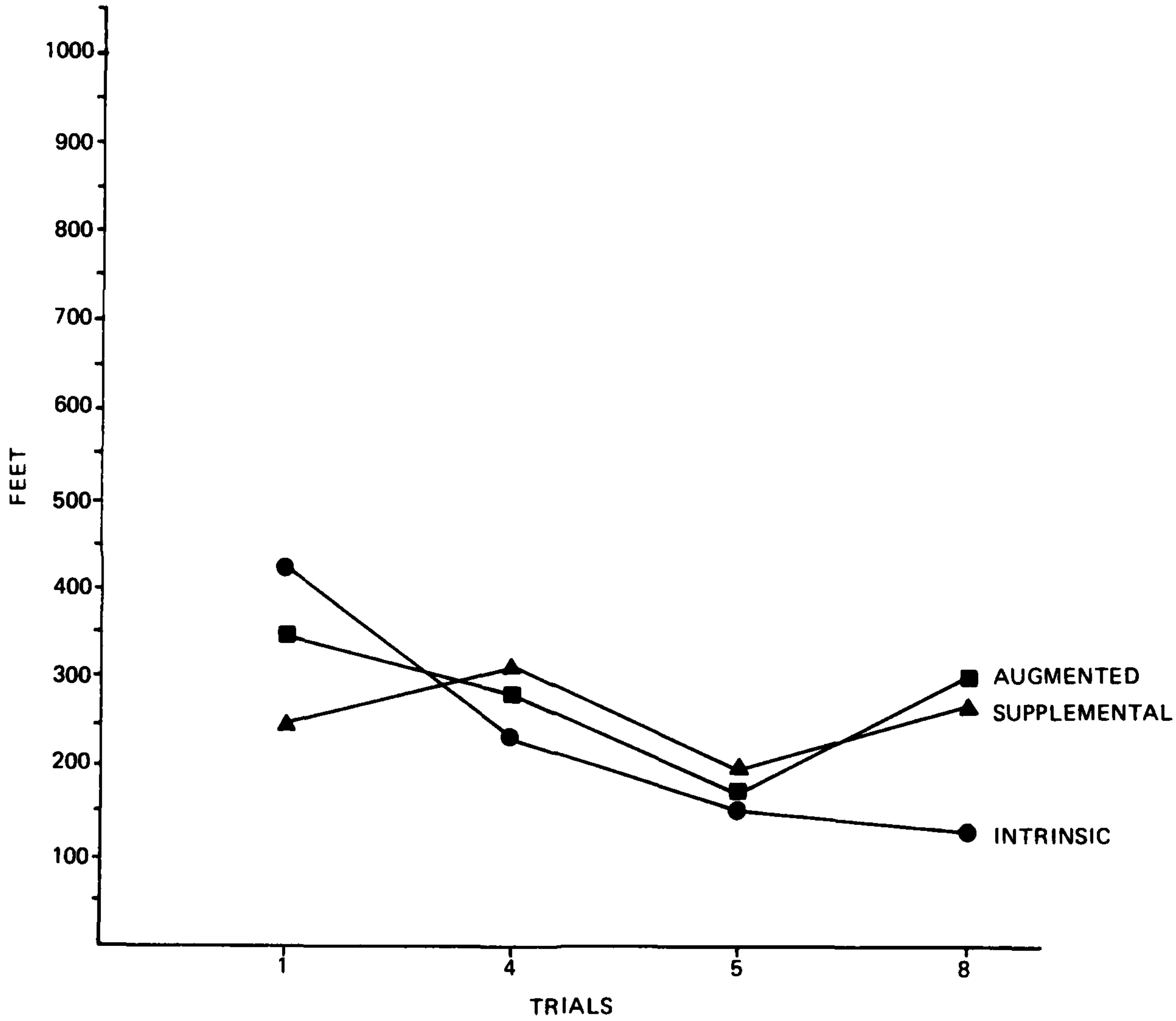

Figure 4. Maximum Port Deviation — Entire Run

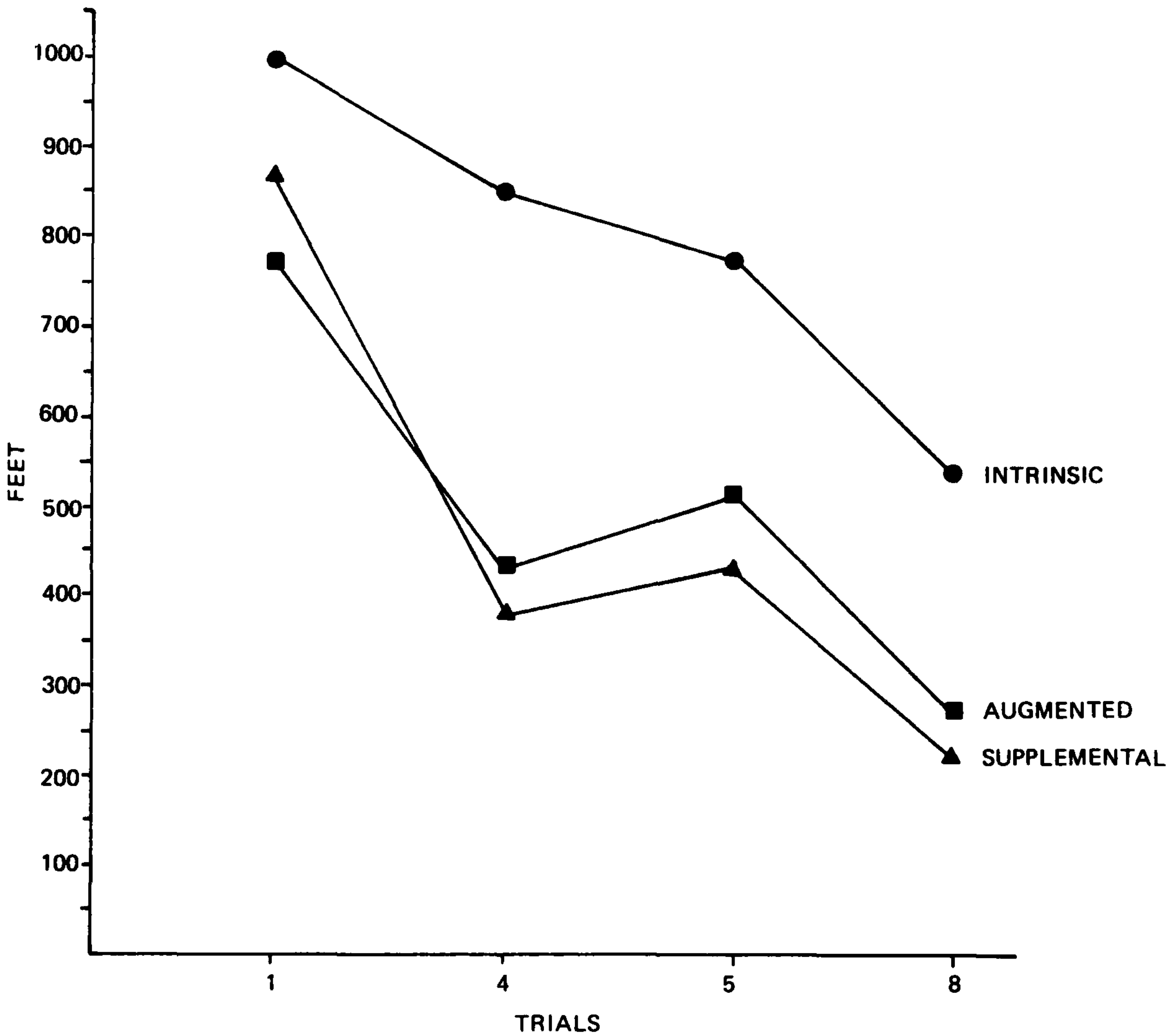

Figure 5. Maximum Starboard Deviation

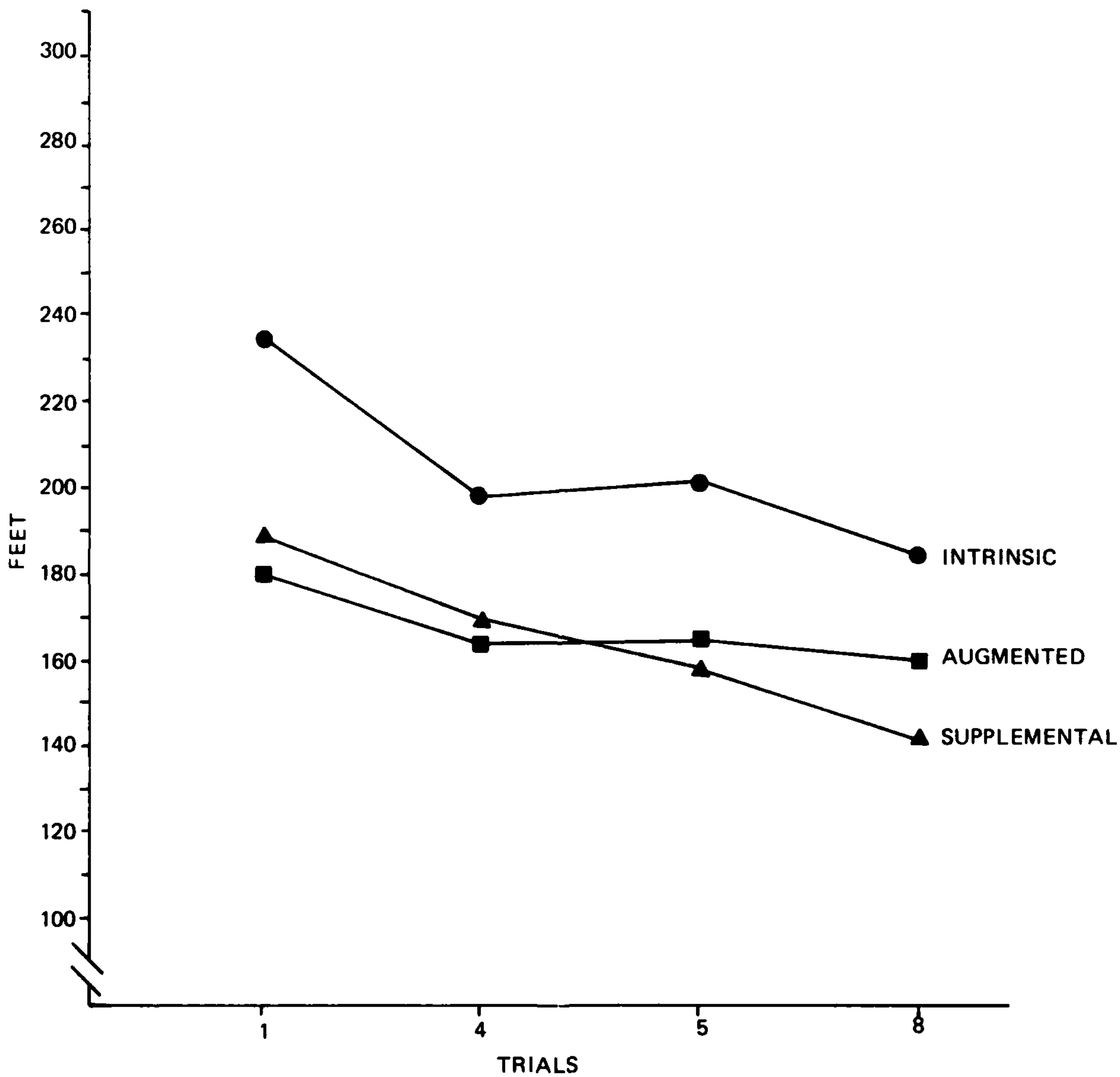

Figure 6. Swept Path — Entire Run

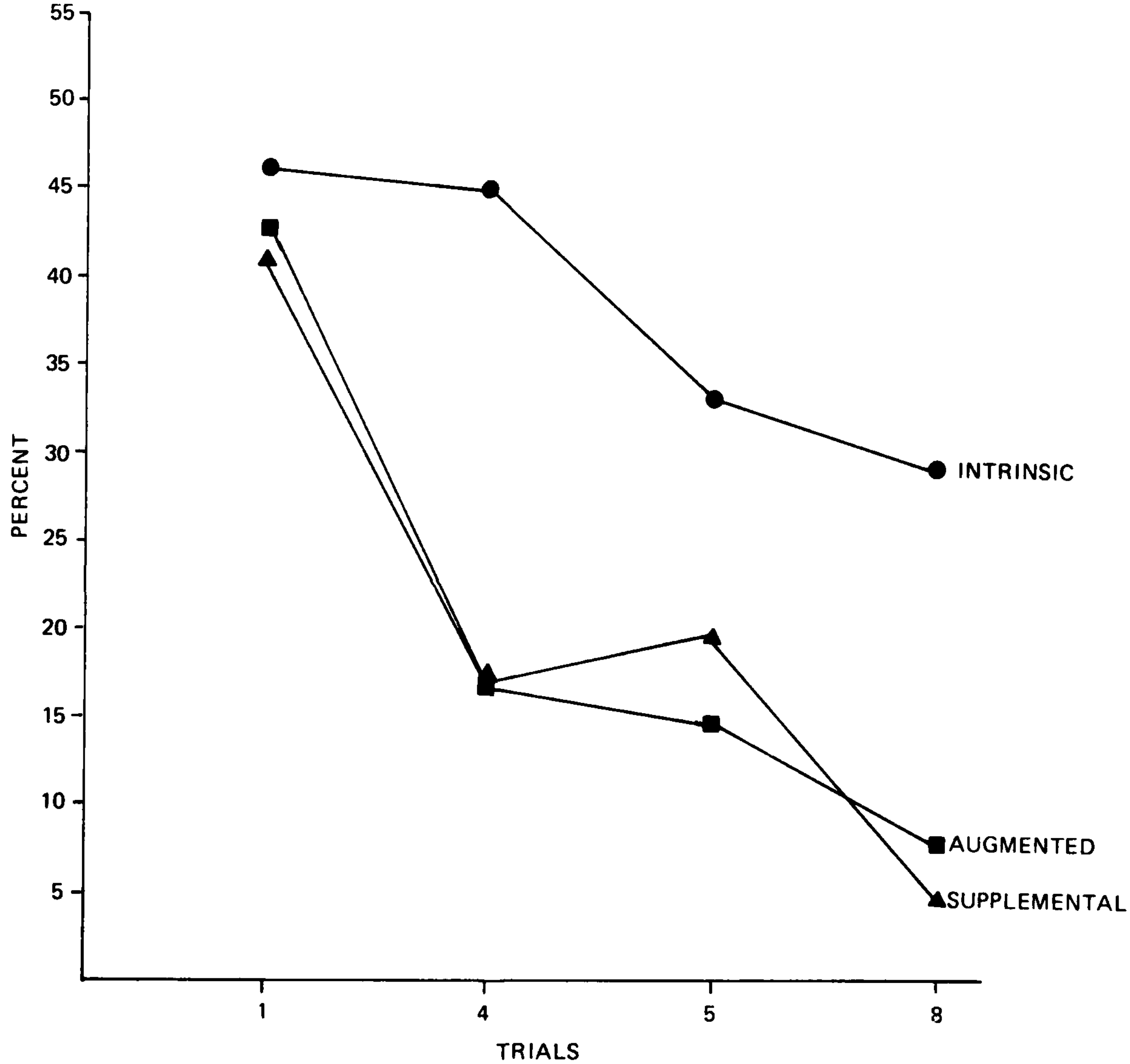

Figure 7. Percent of Time Out of Tolerance Band

significance can be affected by the number of subjects; as seen in this project, the chance of discovering a significant effect was only 0.35. Thus, the non-significant trends in the data become meaningful and at the very least there is no evidence to suggest that supplemental feedback is *not* better than augmented feedback. Further, the nature of the difference between the types of feedback is such that it probably would not become apparent until the later stages of training. It is postulated that this study did not encompass enough time to allow these differences to come out. Even so, the trends in the data tend to support rather than deny that supplemental feedback is better than augmented feedback.

Although few clearly defined differences were obtained between augmented and supplemental feedback in this study, the nature of the data is such that it ought to generate interest in longer, larger scale experiments. The proper use of feedback in training is an important area for future investigation, and this study indicates that the hypotheses suggested deserve further consideration.

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APPENDIX A

MEANS AND STANDARD DEVIATIONS FOR EACH PERFORMANCE MEASURE BROKEN DOWN BY RUN

TABLE A1. MEAN OFF TRACK DEVIATION

Leg A						
Trial No.	Intrinsic		Augmented		Supplemental	
	Mean	SD	Mean	SD	Mean	SD
1	55.89	25.502	140.38	53.30	133.68	82.17
4	161.94	146.84	99.28	89.54	119.14	51.81
5	142.72	103.98	45.77	30.18	54.83	21.82
8	145.02	192.16	68.30	47.76	83.70	48.69

Leg B

1	455.94	249.73	452.01	201.55	470.47	329.5
4	360.25	80.28	213.12	100.26	200.29	104.33
5	310.64	194.01	215.11	96.53	222.22	118.78
8	236.10	153.28	176.29	34.45	115.27	68.90

Leg C

1	580.80	519.68	258.96	214.39	324.78	173.89
4	406.28	339.55	153.61	92.53	196.26	157.58
5	254.66	183.07	213.35	211.45	240.05	230.50
8	349.79	227.82	170.82	90.61	136.01	78.94

Entire Run

1	379.15	259.75	322.54	112.28	339.40	195.29
4	319.15	108.09	169.54	66.15	178.33	91.93
5	254.46	128.68	170.19	55.93	181.13	103.54
8	238.33	153.90	146.46	25.10	112.40	41.42

TABLE A2. MAXIMUM OFF TRACK DEVIATION

Leg A

Trial No.	Intrinsic		Augmented		Supplemental	
	Mean	SD	Mean	SD	Mean	SD
1	205.60	96.34	340.21	237.77	379.00	289.65
4	353.61	266.40	209.19	178.61	275.21	129.82
5	350.59	231.77	99.69	65.70	121.81	44.25
8	306.63	347.84	224.79	145.29	277.02	118.07

Leg B

1	859.66	500.09	852.10	357.50	849.99	730.71
4	808.11	240.92	371.84	208.54	419.72	166.53
5	691.09	404.11	455.10	286.30	405.11	233.87
8	417.56	252.32	354.97	50.04	256.70	113.55

Leg C

1	871.89	746.20	329.28	203.31	429.93	202.04
4	549.07	402.45	246.98	118.72	303.17	195.40
5	413.88	235.67	316.91	272.89	339.69	185.40
8	506.41	277.00	274.57	117.84	195.73	75.47

Entire Run

1	1036.03	711.26	896.48	298.35	897.23	729.36
4	919.69	204.60	428.52	166.09	431.51	161.46
5	781.50	334.41	516.07	303.90	426.20	233.33
8	539.45	287.26	371.80	73.04	298.36	79.84

TABLE A3. MAXIMUM PORT DEVIATION

Leg A						
Trial No.	Intrinsic		Augmented		Supplemental	
	Mean	SD	Mean	SD	Mean	SD
1	133.14	113.04	340.21	237.77	225.52	198.21
4	60.68	42.82	197.79	189.01	275.21	129.82
5	47.19	16.49	99.69	65.70	110.49	58.88
8	45.08	28.93	184.84	166.34	225.38	121.40

Leg B

1	405.39	306.04	271.57	268.31	178.62	216.83
4	67.73	78.16	220.44	137.03	258.32	128.27
5	115.16	95.56	116.06	128.12	143.77	107.41
8	115.53	87.45	286.95	90.10	227.06	95.62

Leg C

1	213.98	340.48	88.92	117.67	73.24	135.29
4	176.42	362.02	84.16	119.24	48.97	90.79
5	60.79	104.99	73.98	127.41	73.31	100.42
8	32.36	53.27	146.17	124.73	96.22	95.75

Entire Run

1	416.84	295.13	340.21	237.76	225.52	198.21
4	234.99	332.27	275.21	147.80	293.13	119.90
5	143.32	98.68	152.42	117.00	164.03	89.60
8	128.98	70.98	303.07	82.31	222.34	72.84

TABLE A4. MAXIMUM STARBOARD DEVIATION

Leg A						
	Intrinsic		Augmented		Supplemental	
Trial No.	Mean	SD	Mean	SD	Mean	SD
1	121.20	111.10	0.00	0.00	172.07	348.28
4	350.14	270.82	26.82	41.79	0.00	0.00
5	350.59	231.77	17.22	27.04	23.46	38.43
8	296.10	250.32	53.86	101.52	8.60	13.41
Leg B						
1	813.75	522.23	719.17	499.25	864.17	753.08
4	808.12	240.92	366.09	214.66	343.60	230.41
5	653.54	458.79	455.10	286.29	367.88	277.76
8	417.56	252.32	227.29	151.59	143.52	135.09
Leg C						
1	710.88	840.55	295.08	206.68	429.93	202.04
4	455.94	394.74	228.43	125.93	284.87	208.81
5	369.46	288.26	263.52	301.07	316.02	204.98
8	506.41	277.00	145.33	199.69	148.98	96.42
Entire Run						
1	1036.03	711.26	896.48	298.35	864.17	753.08
4	919.68	204.00	428.39	166.09	377.76	197.98
5	781.53	333.41	516.07	303.90	417.86	239.71
8	539.45	287.26	371.80	73.04	213.40	185.67

TABLE A5. SWEPT PATH

Trial No.	Intrinsic		Augmented		Supplemental	
	Mean	SD	Mean	SD	Mean	SD
Leg A						
1	184.59	21.23	138.09	27.80	168.14	48.97
4	207.46	34.56	147.38	20.67	157.38	20.49
5	221.79	34.78	161.43	11.64	167.49	11.66
8	217.34	44.10	173.35	18.74	153.99	29.14
Leg B						
1	244.94	79.29	213.77	44.26	210.53	57.41
4	198.88	30.07	172.03	23.95	171.23	30.04
5	194.47	43.15	173.81	41.34	160.55	26.88
8	161.17	97.32	162.10	21.77	144.40	18.28
Leg C						
1	251.92	135.75	154.74	15.52	171.22	42.47
4	185.25	67.89	159.84	24.28	163.47	38.21
5	187.06	51.96	154.16	33.63	148.77	19.76
8	200.50	47.38	138.86	23.99	128.70	7.49
Entire Run						
1	234.18	76.81	180.02	21.06	188.99	44.15
4	199.23	21.34	163.14	16.82	166.58	23.65
5	200.88	35.41	164.37	23.44	159.84	16.24
8	186.51	35.14	160.45	13.68	143.76	18.01

TABLE A6. PERCENT OF TIME OUT OF TOLERANCE BANK

Leg A						
Trial No.	Intrinsic		Augmented		Supplemental	
	Mean	SD	Mean	SD	Mean	SD
1	2.25	3.51	5.47	13.40	10.84	16.61
4	20.85	32.46	6.60	15.41	4.65	6.86
5	20.29	24.00	0.00	0.00	0.00	0.00
8	14.60	27.38	1.79	4.40	2.13	3.45

Leg B

1	62.01	29.81	64.96	17.84	57.69	28.62
4	51.04	10.10	24.37	29.70	22.03	27.31
5	40.04	24.33	21.15	25.07	21.69	30.07
8	30.23	37.25	8.25	6.60	8.81	13.89

Leg C

1	57.07	43.80	36.86	46.50	47.07	46.20
4	56.44	47.14	11.70	26.97	19.72	35.16
5	33.16	42.34	17.24	40.51	33.62	50.80
8	47.43	45.35	10.18	21.68	0.00	0.00

Entire Run

1	46.50	18.90	42.72	13.97	41.91	24.12
4	44.36	13.93	16.74	17.11	16.66	21.05
5	33.45	16.54	14.68	16.32	18.72	26.95
8	29.88	30.86	6.90	5.94	5.00	7.14

APPENDIX B

ANALYSIS OF COVARIANCE SUMMARY TABLES

TABLE B1. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Mean Off Track Deviation — Trial 8 (Entire Run)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Mean Off Track Deviation — Trial 1

Correlation Coefficient: −0.153

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	14240 499	1	14240.499	1.893	0 190
Feedback	61367.088	2	30683.544	4.079	0 040
Error	105320.101	14	7522.864		
Total	180927.688	17	10642.805		

	Intrinsic	Augmented	Supplemental
Mean	238.16	146.46	112.40
SD	153.90	25.10	41.42
Mean Adjusted For Covariate	247.47	140.08	109.46
N	6	6	6

TABLE B2. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Off Track Deviation — Trial 8 (Entire Run)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Off Track Deviation — Trial 1

Correlation Coefficient: −0.104

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	62353.348	1	62353.348	2.288	0.153
Feedback	210465.988	2	105232.994	3.861	0.046
Error	381579.891	14	27255.707		
Total	654399.227	17 ±	38494.072		

	Intrinsic	Augmented	Supplemental
Mean	539.46	371.81	298.37
SD	287.26	73.04	79.84
Mean Adjusted For Covariate	551.16	365.91	292.56
N	6	6	6

TABLE B3. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Port Deviation — Trial 8 (Entire Run)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Port Deviation — Trial 1

Correlation Coefficient: 0.057

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	3371.059	1	3371.059	0.713	0.413
Feedback	119662.800	2	59831.400	12.659	0.001
Error	66171.521	14	4726.537		
Total	189205.379	17	11129.728		

	Intrinsic	Augmented	Supplemental
Mean	128.98	303.07	272.34
SD	70.98	82.31	72.84
Mean Adjusted For Covariate	115.97	301.22	287.21
N	6	6	6

TABLE B4. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Starboard Deviation — Trial 8 (Entire Run)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Starboard Deviation — Trial 1

Correlation Coefficient: 0.039

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	10080.596	1	10080.596	0.244	0.629
Feedback	391410.809	2	195705.404	4.729	0.127
Error	579391.906	14	41385.136		
Total	980883.313	17	57699.019		

	Intrinsic	Augmented	Supplemental
Mean	539.45	265.13	213.40
SD	287.26	169.69	105.67
Mean Adjusted For Covariate	548.08	257.64	212.27
N	6	6	6

TABLE B5. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Swept Path — Trial 8 (Entire Run)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Swept Path — Trial 1

Correlation Coefficient: 0.058

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	174.426	1	174.426	0.256	0.621
Feedback	5671.622	2	2835.811	4.155	0.038
Error	9554 766	14	682.483		
Total	15400.814	17	905.930		

	Intrinsic	Augmented	Supplemental
Mean	186.50	160.44	143.76
SD	38.14	13.68	18.01
Mean Adjusted For Covariate	189.21	158.72	142.77
N	6	6	6

TABLE B6. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Percent of Time Out of the Tolerance Band — Trial 8 (Entire Run)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Percent of Time Out of the Tolerance Band — Trial 1

Correlation Coefficient: −0.383

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	841.838	1	841.838	2.949	0.108
Feedback	2654.648	2	1327.324	4.649	0.028
Error	3997.035	14	285.503		
Total	7493.521	17	440.795		

	Intrinsic	Augmented	Supplemental
Mean	29.88	6.91	5.00
SD	30.86	5.94	7.14
Mean Adjusted For Covariate	31.16	6.45	41.8
N	6	6	6

TABLE B7. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Mean Off Track Deviation — Trial 4 (Entire Run)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Mean Off Track Deviation — Trial 1

Correlation Coefficient: 0.048

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	1417.743	1	1417.743	0.162	0.693
Feedback	83334.949	1	41667.475	4.767	0.026
Error	122361.593	14	8740.114		
Total	207117.285	17	12183.193		

	Intrinsic	Augmented	Supplemental
Mean	319.14	169.54	178.34
SD	108.08	66.5	91.93
Mean Adjusted For Covariate	319.95	168.98	178.08
N	6	6	6

TABLE B8. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Off Track Deviation — Trial 4 (Entire Run)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Off Track Deviation — Trial 1

Correlation Coefficient: 0.051

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	14909.042	1	14909.042	0.430	0.523
Feedback	944876.633	2	472438.316	13.617	0.001
Error	485728.656	14	34694.904		
Total	1445514.328	17	85030.255		

	Intrinsic	Augmented	Supplemental
Mean	919.69	428.39	431.35
SD	204.60	166.09	166.46
Mean Adjusted For Covariate	919.37	428.55	431.52
N	6	6	6

TABLE B9. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Starboard Deviation — Trial 4 (Entire Run)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Starboard Deviation — Trial 1

Correlation Coefficient: 0.123

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	100989.421	1	100989.421	2.413	0.143
Feedback	623806.953	2	311903.477	7.451	0.006
Error	586049.234	14	41860.660		
Total	1310845.609	17	77108.565		

	Intrinsic	Augmented	Supplemental
Mean	812.89	427.71	377.6
SD	228.54	186.00	197.99
Mean Adjusted For Covariate	802.92	436.37	378.91
N	6	6	6

TABLE B10. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Swept Path — Trial 4 (Entire Run)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Swept Path — Trial 1

Correlation Coefficient: 0.104

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	555.160	1	555.160	1.209	0.290
Feedback	4212.827	2	2106.413	4.586	0.029
Error	6430.272	14	459.305		
Total	11198.259	17	658.721		

	Intrinsic	Augmented	Supplemental
Mean	199.06	163.17	166.58
SD	21.34	16.82	23.65
Mean Adjusted For Covariate	200.29	162.39	166.13
N	6	6	6

TABLE B11. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Percent of Time Out of the Tolerance Band — Trial 4 (Entire Run)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Sup,. emental)

Covariate: Percent of Time Out of the Tolerance Band — Trial 1

Correlation Coefficient: 0.201

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	231.467	1	231.467	0.710	0.414
Feedback	2912.525	2	1456.262	4.465	0.032
Error	4565.613	14	326.115		
Total	7709.605	17	453.506		

	Intrinsic	Augmented	Supplemental
Mean	44.36	16.74	16.66
SD	13.93	17.11	21.05
Mean Adjusted For Covariate	44.02	16.86	16.88
N	6	6	6

TABLE B12. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Port Deviation — Trial 4 (Entire Run)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Port Deviation — Trial 5

Correlation Coefficient: 0.281

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	12476.282	1	12476.282	2.259	0.155
Feedback	99410.767	2	49705.383	9.000	0.003
Error	77218.330	14	5522.738		
Total	189205.379	17	11129.728		

	Intrinsic	Augmented	Supplemental
Mean	128.98	303.07	272.34
SD	70.98	82.31	72.84
Mean Adjusted For Covariate	131.26	303.27	269.87
N	6	6	6

TABLE B13. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Swept Path — Trial 8 (Leg A)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Swept Path — Trial 1 (Leg A)

Correlation Coefficient: 0.089

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	197.044	1	197.044	0.180	0.678
Feedback	12883.217	2	6441.609	5.884	0.014
Error	15327.875	14	1094.848		
Total	28408.137	17	1671.067		

	Intrinsic	Augmented	Supplemental
Mean	217.35	173.36	154.00
SD	44.09	18.94	29.14
Mean Adjusted For Covariate	220.60	169.42	154.70
N	6	6	6

TABLE B14. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Port Deviation — Trial 4 (Leg A)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Port Deviation — Trial 1

Correlation Coefficient: 0.054

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	1937.126	1	1937.126	0.101	0.755
Feedback	145036.322	2	71518.161	3.726	0.050
Error	268723.102	14	19194.507		
Total	413696.551	17	24335.091		

	Intrinsic	Augmented	Supplemental
Mean	60.67	197.79	275.21
SD	42.82	189.01	129.82
Mean Adjusted For Covariate	52.86	206.19	274.62
N	6	6	6

TABLE B15. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Starboard Deviation — Trial 4 (Leg A)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Starboard Deviation — Trial 1

Correlation Coefficient: −0.007

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	34.559	1	34.559	0.001	0.972
Feedback	457867.969	2	228933.984	8.587	0.004
Error	373258.512	14	26661.322		
Total	831161.039	17	48891.826		

	Intrinsic	Augmented	Supplemental
Mean	350.14	26.81	0
SD	270.82	41.79	0
Mean Adjusted For Covariate	351.47	21.20	4.28
N	6	6	6

TABLE B16. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Swept Path — Trial 4 (Leg A)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Swept Path — Trial 1

Correlation Coefficient: 0.237

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	1398.057	1	1398.057	1.938	0.186
Feedback	11247.084	2	5623.542	7.794	0.005
Error	10100.890	14	721.492		
Total	22746.031	17	1338.002		

	Intrinsic	Augmented	Supplemental
Mean	207.46	147.38	157.38
SD	34.86	20.67	20.49
Mean Adjusted For Covariate	208.72	144.64	157.87
N	6	6	6

TABLE B17. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Off Track Deviation — Trial 5 (Leg A)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Off Track Deviation — Trial 4

Correlation Coefficient: 0.589

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	229092.686	1	229092.686	18.768	0.01
Feedback	131562.600	2	65781.300	5.389	0.018
Error	170889.309	14	12206.379		
Total	531544.594	17	31267.329		

	Intrinsic	Augmented	Supplemental
Mean	350.59	99.69	121.80
SD	231.77	65.70	44.25
Mean Adjusted For Covariate	270.6	139.24	162.23
N	6	6	6

TABLE B18. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Port Deviation — Trial 8 (Leg B)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Port Deviation — Trial 1

Correlation Coefficient: 0.030

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	1099.823	1	1099.823	0.139	0.715
Feedback	103702.853	2	51851.426	6.566	0.010
Error	110557.532	14	7896.967		
Total	215360.207	17	12668.247		

	Intrinsic	Augmented	Supplemental
Mean	115.54	286.95	227.06
SD	87.45	90.11	95.62
Mean Adjusted For Covariate	101.75	288.52	239.28
N	6	6	6

TABLE B19. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Mean Off Track Deviation — Trial 4 (Leg B)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Mean Off Track Deviation — Trial 1

Correlation Coefficient: 0.159

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	26696.537	1	26696.537	3.432	0.085
Feedback	96106.854	2	48053.427	6.177	0.012
Error	108912.844	14	7779.489		
Total	231716.234	17	13630.368		

	Intrinsic	Augmented	Supplemental
Mean	360.26	231.12	200.29
SD	80.28	100.26	104.33
Mean Adjusted For Covariate	360.83	214.33	298.50
N	6	6	6

TABLE B20. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Off Track Deviation — Trial 4 (Leg B)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Off Track Deviation — Trial 1

Correlation Coefficient: 0.048

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	10440.421	1	10440.421	0.230	0.639
Feedback	688655.867	2	344327.934	7.601	0.006
Error	634195.492	14	45299.678		
Total	1333291.781	17	78428.929		

	Intrinsic	Augmented	Supplemental
Mean	808.11	371.84	419.72
SD	240.92	208.54	166.53
Mean Adjusted For Covariate	808.59	372.70	418.37
N	6	6	6

TABLE B21. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Starboard Deviation — Trial 4 (Leg B)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Starboard Deviation — Trial 1

Correlation Coefficient: 0.120

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	79039.430	1	79039.430	1.551	0.233
Feedback	817126.195	2	408563.098	8.020	0.005
Error	713243.906	14	50945.993		
Total	1609409.531	17	94671.148		

	Intrinsic	Augmented	Supplemental
Mean	808.12	366.1	284.88
SD	240.92	214.663	208.81
Mean Adjusted For Covariate	806.42	375.33	336.07
N	6	6	6

TABLE B22. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Port Deviation — Trial 8 (Leg B)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Port Deviation — Trial 5

Correlation Coefficient: 0.005

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	3.611	1	3.611	0.000	0.985
Feedback	10989.461	1	10989.461	1.149	0.312
Error	86076.702	9	9564.078		
Total	97069.774	11	8824.525		

	Intrinsic	Augmented	Supplemental
Mean	115.54	286.95	227.05
SD	87.45	90 105	95.62
Mean Adjusted For Covariate	115.55	287.51	226.49
N	6	6	6

TABLE B23. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Mean Off Track Deviation — Trial 8 (Leg C)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Mean Off Track Deviation — Trial 1

Correlation Coefficient: −0.092

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	17708.933	1	17708.933	1.061	0.320
Feedback	238195.145	2	119097.572	7.135	0.007
Error	233698.641	14	16692.760		
Total	489602.719	17	28800.160		

	Intrinsic	Augmented	Supplemental
Mean	349.79	170.81	136.01
SD	227.82	90.61	78.94
Mean Adjusted For Covariate	395.62	140.07	120.92
N	6	6	6

TABLE B24. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Off Track Deviation — Trial 8 (Leg C)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Off Track Deviation — Trial 1

Correlation Coefficient: 0.046

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	9057.874	1	9057.874	0.389	0.543
Feedback	459600.281	2	229800.141	9.873	0.002
Error	325867.977	14	23276.284		
Total	794526.133	17	46736.832		

	Intrinsic	Augmented	Supplemental
Mean	506.41	274.57	195.73
SD	276.99	117.84	75.47
Mean Adjusted For Covariate	578.86	227.24	170.62
N	6	6	6

TABLE B25. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Starboard Deviation — Trial 8 (Leg C)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Starboard Deviation — Trial 1

Correlation Coefficient: −0.013

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	718.002	1	718.002	0.018	0.895
Feedback	593883.969	2	296941.984	7.542	0.006
Error	551217.422	14	39372.673		
Total	1145819.391	17	67401.141		

	Intrinsic	Augmented	Supplemental
Mean	506.42	145.33	148.98
SD	276.99	199.69	96.42
Mean Adjusted For Covariate	538.93	119.63	142.16
N	6	6	6

TABLE B26. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Swept Path — Trial 8 (Leg C)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Swept Path — Trial 1

Correlation Coefficient: 0.149

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	3010.018	1	3010.018	2.949	0.108
Feedback	15199.446	2	7599.723	7.446	0.006
Error	14288.282	14	1020.592		
Total	32497.746	17	1911.632		

	Intrinsic	Augmented	Supplemental
Mean	200.5	138.86	128.7
SD	47.38	23.99	7.49
Mean Adjusted For Covariate	202.29	137.72	128.05
N	6	6	6

TABLE B27. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Percent of Time Out of the Tolerance Band — Trial 8 (Leg C)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Percent of Time Out of the Tolerance Band — Trial 1

Correlation Coefficient: −0.206

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	1375.130	1	1375.130	1.910	0.189
Feedback	8661.366	2	4330.683	6.014	0.013
Error	10080.682	14	720.049		
Total	20117.178	17	1183.363		

	Intrinsic	Augmented	Supplemental
Mean	47.43	10.18	0
SD	45.35	21.68	0
Mean Adjusted For Covariate	50.30	7.27	0.02
N	6	6	6

TABLE B28. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Mean Off Track Deviation — Trial 4 (Leg C)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Mean Off Track Deviation — Trial 1

Correlation Coefficient: 0.096

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	19201.906	1	19201.906	0.439	0.519
Feedback	330961.508	2	165480.754	3.780	0.049
Error	612835.438	14	43773.960		
Total	962998.852	17	56646.991		

	Intrinsic	Augmented	Supplemental
Mean	406.28	153.61	196.26
SD	339.55	92.53	157.59
Mean Adjusted For Covariate	459.19	118.11	178.85
N	6	6	6

TABLE B29. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Maximum Off Track Deviation — Trial 8 (Leg C)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Maximum Off Track Deviation — Trial 5

Correlation Coefficient: 0.391

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	130311.761	1	130311.761	4.472	0.053
Feedback	256219.471	2	128109.735	4.396	0.033
Error	407994.902	14	29142.293		
Total	794526.133	17	46736.832		

	Intrinsic	Augmented	Supplemental
Mean	506.41	274.57	195.73
SD	276.99	117.84	75.47
Mean Adjusted For Covariate	489.34	286.51	200.86
N	6	6	6

TABLE B30. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Swept Path — Trial 8 (Leg C)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Swept Path — Trial 5

Correlation Coefficient: 0.607

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	9669.186	1	9669.186	10.814	0.005
Feedback	10310.079	2	5155.040	5.765	0.015
Error	12518.481	14	894.177		
Total	32497.746	17	1911.632		

	Intrinsic	Augmented	Supplemental
Mean	200.50	138.86	128.7
SD	47.38	23.99	7.49
Mean Adjusted For Covariate	193.45	141.59	133.02
N	6	6	6

TABLE B31. SUMMARY TABLE FOR ANALYSIS OF COVARIANCE

Dependent Variable: Percent of Time Out of the Tolerance Band — Trial 8 (Leg C)

Independent Variables: Feedback Condition (Intrinsic, Augmented, Supplemental)

Covariate: Percent of Time Out of the Tolerance Band — Trial 5

Correlation Coefficient: 0.262

Source of Variance	Sums of Squares	DF	Mean Square	F Ratio	P
Covariate	2139.993	1	2139.993	2.764	0.119
Feedback	7137.891	2	3568.946	4.610	0.029
Error	10839.294	14	774.235		
Total	20117.178	17	1183.363		

	Intrinsic	Augmented	Supplemental
Mean	47.43	10.18	0
SD	45.35	21.68	0
Mean Adjusted For Covariate	46.17	12.81	−1.37
N	6	6	6

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APPENDIX C

SUBJECT INSTRUCTIONS

Welcome to CAORF. Thank you for participating in this research project. Your task will be to pilot a 65,000 DWT tanker outbound through Valdez Narrows. Using your piloting skills, your goal will be to maintain the recommended trackline from point D to point A (illustrated on the Valdez Narrows chart) as precisely as possible.

The ship will be underway at 6 knots at the beginning of the run. You may adjust the RPM during the transit, bearing in mind that local regulations require that you maintain a speed of no more than 6 knots during the outbound passage. An experienced helmsman will man the wheel and respond to your course and rudder commands. All the bridge equipment, with the exception of the bow and stern thrusters will be operational and may be utilized as you would in the real world.

The environmental conditions will simulate average conditions at the Port of Valdez. The current is fairly constant in the narrows at about 0.5 knots in a southwesterly direction. Wind is out of the NNE at about 20 knots in Port Valdez and increases to 40 knots from the North in the narrows. Visibility will be about 15 miles in daylight.

Each transit will take about 45 minutes to complete. During your second, third, fifth and sixth runs, you will be provided with a true motion situation display. Use the situation display to obtain feedback as your ship's motion and position in the channel. (To be included in the instructions for supplemental feedback subjects.)

Following the second, third, fifth and sixth runs, you will be taken to a room where a trainer/instructor will point out on a trackplot of ownship where the choice, and/or timing of a ship maneuver resulted in less than optimal performance.

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